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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 579

Joint Contribution from the Bureau of Plant Industry, WM. A. TAYLOR, Chief, and the Bureau of Markets, CHARLES J. BRAND, Chief

Washington, D. C. ▼ September 5, 1917

CELERY STORAGE EXPERIMENTS.[1]

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INTRODUCTION.

Celery is one of the important truck crops grown in the United States. The farm value of the crop of 1909 was $3,922,848, of which crop eight States, New York, Michigan, Florida, California, Massachusetts, Ohio, Pennsylvania, and New Jersey, produced about 86 per cent. The six northern States mentioned produce about two-thirds of the celery grown in the United States, and as a considerable portion of this is stored for a period of one to three months the merchan-

[1] The writer wishes to acknowledge his indebtedness to Mr. C. C. Locke, of Arkport, N. Y., Mr. Henry Greffrath, South Lima, N. Y., and Mr. W. P. Rodgers, Williamson, N. Y., for their courtesy in allowing him to select from their fields the celery used in these experiments; also to the managers of the Hygeia Refrigerating Co., Elmira, N. Y., the Hornell Ice & Storage Co., Hornell, N. Y., and the Williamson Ice & Storage Co., Williamson, N. Y., in whose houses the experimental lots of celery were stored, for valuable assistance rendered.

NOTE.—The fruit and vegetable handling, transportation, and storage investigations formerly administered in the Office of Horticultural and Pomological Investigations of the Bureau of Plant Industry are now being prosecuted jointly and cooperatively by the Bureau of Plant Industry and the Bureau of Markets.

dising value of the crop is much greater than the farm value given in the above figures. With better methods of storage the value would be still further increased.

To hold celery in cold-storage warehouses is a comparatively new undertaking, and for this reason very little definite information is available on the subject. Storing celery in pits in the field and in common storages of the cellar type has been practiced for a long time, but these methods are not satisfactory because the temperature and moisture conditions can not be controlled.

During some seasons celery banked in the field keeps in good condition for several months, while during other seasons the crop decays in a short time. When the weather is warm and moist during the storage period, celery in banks or pits usually decays. Sometimes the crop is considerably injured by freezing. Even if celery could be stored in pits in the field with very little loss, the method would not be entirely satisfactory, because conditions are not always favorable for its removal when wanted for market. The greatest market demand often occurs during a rainy period or during very cold weather when it is difficult to remove celery from banks or pits.

As celery is quite perishable, often decaying in a very short time, most storage-house managers prefer to handle other products. For this reason it is becoming very difficult for celery growers and dealers to secure storage space for their product. If it could be shown that celery which reaches the storage house in good condition can be held in a satisfactory condition under refrigeration for a period of three months or more, there would be less difficulty in securing storage space for celery. It is believed that the data presented in this bulletin prove that celery can be held in good condition for that length of time. In every instance where the celery showed considerable decay under three months the conditions in the storage room were not good. In most cases, however, the experimental lots of celery kept in good condition until the room was nearly empty, when the room temperature for a few days was not properly regulated. It should be added, however, that celery which reaches the storage house very badly diseased or in a heated condition will not keep as long as that which reaches the house in good condition. The management should not be held responsible for loss due to poor methods of handling before the celery reaches the storage house.

A clear knowledge of the factors which cause or hasten the decay of celery in storage and the methods that can be employed to lessen this loss is essential to successful celery storage. As has been stated, if storage-house managers know that celery which reaches the storage house in good condition can be held for a period of three months with very little loss, they will more readily accept

celery for storage. Also, if growers and dealers realize that for satisfactory results celery must be properly handled before it reaches the storage house, they will use more care in preparing the crop for storing.

PRELIMINARY STUDY.

Before starting the investigational work, which was continued for a period of four years, a preliminary study of the conditions prevailing in storage houses and on the market was made. It was observed that celery held for two or three months nearly always showed some decay and that this decay developed faster in the center than in outer parts of the crate. In many instances the stored celery was so badly decayed that the tops had the appearance of being scooped out in the center of the crate.

It was also observed that the large crates were often so badly broken when they reached the market that the celery was considerably injured, and in many cases the crates had to be repaired or entirely remade. The crates when filled with celery were so heavy that they were broken in ordinary handling, especially in loading in the field and in loading and unloading at the storage house and at the market.

Under ordinary conditions the celery is loaded on a wagon in the field and unloaded from the wagon into cars for shipment to the storage house. At the storage house it is taken from the car, placed on hand trucks, and transferred to the storage room, where it is unloaded and piled four, five, or six crates high. When the celery is ready for shipment to market it is again transferred on hand trucks and loaded into cars. At the market center it is loaded into wagons or motor trucks and hauled to and unloaded at the wash rooms. Sometimes the crated celery is handled two or three times more before it reaches the retailer. With this amount of handling it can be readily seen that the crates would have to be very strongly made to prevent breakage. When the crates are badly broken, the celery stalks are often crushed and the injured portions offer entrance for decay-producing organisms.

OBJECTS AND OUTLINE OF THE EXPERIMENTS.

The main objects of the experimental work were as follows:

(1) To determine the factors which hasten decay in celery in storage houses.

(2) To determine the best method or methods of reducing the loss of celery in storage due to decay and mechanical injury.

(3) To determine the best type of crate in which to pack celery to be held in a cold-storage warehouse.

(4) To study the effect of the temperature of the storage room on the keeping quality of celery.

The celery used in the experiments during the four years was grown and stored in western New York. Each experimental lot was packed in the field and graded in the storage house by representatives of the Department of Agriculture. In every instance the celery used was free from disease and was so handled that the different lots were comparable. Each year's results are given separately, as the length of the storage period was not the same and the celery was not stored in the same house every year.

The crates used in the experiments were as follows:

(1) The standard crate, which ranges in size from 22 by 22 to 24 by 24 inches, although generally measuring 22 by 23 or 23 by 24 inches.

(2) The partition-ventilated crate, which is the standard crate with a ventilated partition through the center, as shown in figures 1 and 2. This partition is made by nailing three or four slats on each side of 1 or 1¼ inch posts. The slats and posts are the same size as those used for the sides and ends of the crates.

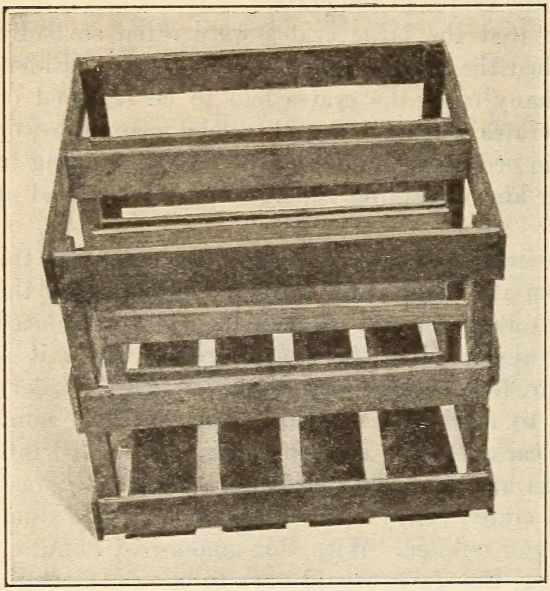

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FIG. 1.—Partition crate used in the celery storage experiments.

(3) The 16-inch crate, 16 inches wide and the same length and depth as the standard crate.

(4) The 14-inch crate, 14 inches wide and the same length and depth as the standard crate.

(5) The 10-inch crate, 10 inches wide and the same length and depth as the standard crate.

(6) The 11-inch solid-head crate, 11 inches wide, 24 inches long, and 24 inches deep.

In 1912–13 the standard, the partition-ventilated, and the 10-inch crates were used. In 1913–14, 1914–15, and 1915–16 the standard and partition-ventilated crates were used, but the 10-inch crate was discarded after the first year, because it was too small for practical purposes. Each year after 1912–13 the 14-inch and the 16-inch crates were used.

Figure 3 shows a 14-inch, a 16-inch, and a partition-ventilated crate filled with celery. The 11-inch solid-head crate was used at Williamson in 1914–15 and at Williamson and Hornell in 1915–16. In every case where the partition crate is mentioned, the reference is to the standard crate with the ventilated partition in the center.

EXPERIMENTS IN 1912–13.

The celery used in the experiment in 1912–13 was grown at Arkport and stored at Elmira, N. Y. The experimental lots were harvested in the afternoon of October 18, 1912, and shipped the same day by express to Elmira. The following morning they were unloaded and stacked in the storage house. The crates were piled five high, with a 2-inch scantling between the crates and a 2 to 3 inch air space between the stacks. The celery was examined three times while in storage, and at the third examination, February 13, 1913, it was graded. The results of this grading are shown in Table I.

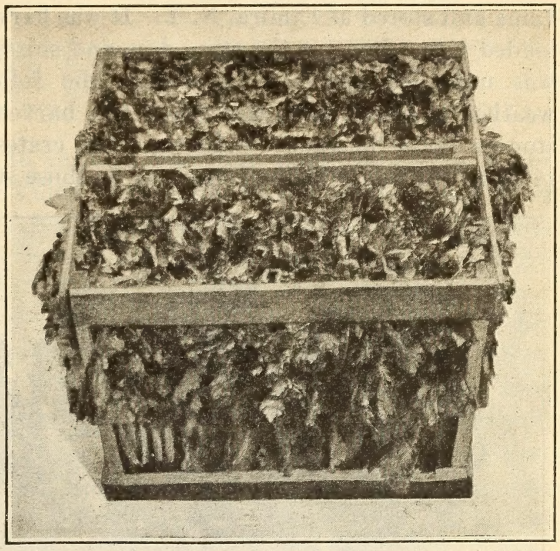

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FIG. 2.—Partition crate filled with celery. Note the air space, which extends to the bottom of the crate.

The sound celery was free from disease, or so slightly diseased that very few of the leaves had to be stripped off in preparing it for market. The slightly decayed celery consisted of stalks which were diseased and required so much stripping that the bunches were small and contained little foliage. The ordinary ratio of the price of these two grades would be about 5 to 3. In other words, if a bunch of 12 stalks of sound celery sells for 50 cents, a bunch of slightly decayed celery would sell for about 30 cents.

TABLE I.—*Relative keeping quality of celery stored in different types of crates, as indicated by the number of stalks of the different grades found in the several types stored at Elmira, N. Y., when inspected on February 13, 1913.*

Type of crate.	Total number of stalks.	Sound.		Slightly decayed.	
		Number.	Per cent.	Number.	Per cent.
Standard	430	305	70.9	125	29.1
Partition	416	395	94.95	21	5.05
10-inch	200	194	97.0	6	3.0

Table I shows that the partition crate contained 24 per cent and the 10-inch crate about 26 per cent more sound celery than the

standard crate. The difference in the amount of decay in different parts of the standard crate was very noticeable, while in the other crates there was very little difference.

EXPERIMENTS IN 1913–14.

The celery used in the experiment in 1913–14 was grown at South Lima and stored at Elmira, N. Y. It was harvested October 29, 1913, loaded into a box car the same day, and shipped to Elmira, where it was unloaded and put in storage the following morning. The weather was cold when this celery was harvested, and it reached the storage house in good condition. The crates, 10 in each lot, were piled in the house in the same way as those stored in 1912–13.

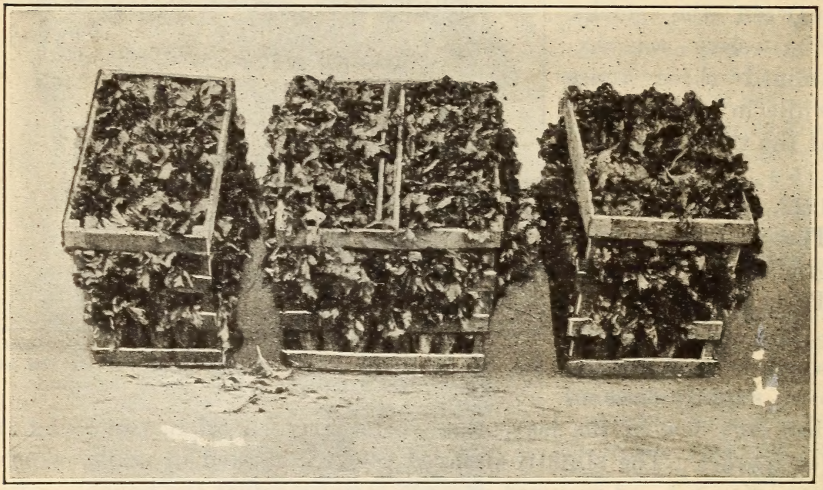

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FIG. 3.—Three different types of crates used in the celery storage experiments: The 14-inch crate on the left, the partition crate in the center, and the 16-inch crate on the right.

After the celery had been in storage about 2½ months, half of it was sold without grading. Notes, however, were taken on its appearance, and while none of it had decayed to any considerable extent, there was a great deal of difference in the color of the foliage in the several crates. The tops of the celery in the standard crate had turned yellow, and decay had started in the center of the crate. The dealer who handled this shipment stated that the celery in the standard crate was worth from 10 to 15 per cent less than that in the partition crates and in the smaller crates.

The remaining five crates of each lot of celery were taken out on February 13, 1914, and carefully graded. The results are given in Table II.

TABLE II.—*Relative keeping quality of celery stored in different types of crates, as indicated by the number of stalks of the different grades found in the several types stored at Elmira, N. Y., when inspected on February 13, 1914.*

Type of crate.	Total number of stalks.	Sound.		Slightly decayed.		Badly decayed.		Worthless.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Standard	615	230	37.4	240	39.0	115	18.7	30	4.9
Partition	480	310	65.0	135	28.0	25	5.0	10	2.0
16-inch	430	335	77.9	78	18.0	17	4.0	0	0
14-inch	370	300	81.0	60	16.2	10	2.7	0	0

The celery harvested in 1913–14 was quite small, because a severe freeze on September 14 killed the outside leaves, necessitating more stripping than usual. Table II shows that the celery was separated into four grades. The sound and slightly decayed grades corresponded to those used in 1912–13. "Badly decayed" consisted of celery so badly diseased that when the stalks were prepared for market only hearts remained. "Worthless" consisted of stalks which were completely decayed and therefore a total loss. The standard crates contained less sound and more slightly decayed, badly decayed, and worthless celery than any of the other crates. The largest percentage of sound celery was in the 14-inch crates, followed by the 16-inch, the partition, and the standard crates, in the order given. Nearly 5 per cent of the celery in the standard crate was a total loss, and over 18½ per cent was hearts.

EXPERIMENTS IN 1914–15.

In the 1914–15 experiments, the celery was secured from two different localities, half being grown at Arkport and stored at Hornell, N. Y., and the other half being grown and stored at Williamson, N. Y. Records were kept to determine the relative development of decay in celery in crates in the different tiers. The top tier always showed more rot than any other.

The celery from Arkport and Williamson was grown and handled under such different conditions that it seems advisable to give the results separately.

CELERY GROWN AT ARKPORT.

At Arkport six lots of five crates each were packed, as follows:

Lot 1.—Standard crate. The celery in this lot was harvested on October 19, while still wet after a rain, and hauled direct to a box car.

Lot 2.—Standard crate. This celery was harvested on October 19, when dry, and left exposed to the sun for about five hours before being loaded into the car.

Lot 3.—Standard crate.

Lot 4.—Partition-ventilated crate.
Lot 5.—16-inch crate.
Lot 6.—14-inch crate.

Lots 3, 4, 5, and 6 were harvested on October 20, while the celery was dry, and loaded immediately into a box car. The car, which was left on the siding until the last of the celery was loaded, was delivered to the storage house the same evening, October 20, but it was not unloaded until the following afternoon, about 5 o'clock. This celery was graded on January 22, 1915, with the results given in Table III.

TABLE III.—*Relative keeping quality of celery stored in different types of crates, as indicated by the number of stalks of the different grades found in the several lots stored at Hornell, N. Y., when inspected on January 22, 1915.*

Lot No. and type of crate.	Total number of stalks.	Sound.		Slightly decayed.		Badly decayed.		Worthless.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
1, standard	429	199	46.7	193	45.3	37	8.0	0	0
2, standard	391	167	41.7	174	46.2	49	12.1	1	.2
3, standard	412	195	47.3	195	47.3	21	5.0	1	.2
4, partition	348	274	78.7	70	20.1	4	1.1	0	0
5, 16-inch	272	235	86.4	37	13.6	0	0	0	0
6, 14-inch	261	243	93.1	18	6.9	0	0	0	0

Table III shows that there was little difference in the keeping quality of the celery in the first three lots. Lot No. 2, which was exposed to the sun for about five hours, had the smallest percentage of sound celery. By comparing lots 3, 4, 5, and 6 it will be seen that the partition crate and the two smaller crates gave much better results than the standard crate. The 14-inch crate gave the best results, followed by the 16-inch crate and the partition crate in the order given. In the standard crate, less than one-half of the celery was sound, while in the 14-inch crate 93 per cent was of that grade.

Table IV shows the relative keeping quality of celery stored at different heights in the Hornell storage house. Each of the six lots was piled in a separate stack, five crates high. These piles were 2 to 3 inches apart, and the crates in each pile were separated by 2 by 2 inch scantlings. The tiers as given in Table IV included one crate from each of the six lots.

It will be noticed that the celery in the bottom tier kept much better than that in any other. At the time the celery was graded the top tier contained only about one-third as much sound celery as the bottom tier.

The celery stored at Hornell was held until February 8, 1915, but as there had been no other celery in the room for two or three weeks preceding that date, it was difficult to maintain the proper tempera-

ture, and the experimental celery was badly frozen. For this reason it was not graded a second time.

TABLE IV.—*Relative keeping quality of celery stored at different heights in the storage room, as indicated by the number of stalks of the different grades in each of the five tiers of crates at Hornell, N. Y., when inspected on January 22, 1915.*

Tier.	Total number of stalks.	Sound.		Slightly decayed.		Badly decayed.		Worthless.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
First (bottom)	428	386	90.2	41	9.5	0	0.3	0	0
Second	412	283	68.7	128	31.0	1	.3	0	0
Third	426	293	68.8	131	30.7	2	.5	0	0
Fourth	414	216	52.1	195	47.1	3	.8	0	0
Fifth (top)	434	135	31.1	192	44.2	105	24.2	2	.5

CELERY GROWN AT WILLIAMSON.

The celery grown and stored at Williamson was harvested and packed in the afternoon of October 23, 1914, and hauled to the storage house the same afternoon. This celery was large, free from disease, and blanched nearly enough for market.

Five crates each of five different types were used, as follows: (1) Standard crate, (2) partition-ventilated crate, (3) 16-inch crate, (4) 14-inch crate, (5) 11-inch solid-head crate.

The crates were of the same length and depth, the difference in size being in width only. Each lot of five crates was piled five high, with 3 or 4 inches between the crates in the piles. The celery was examined on January 20, 1915, but was not graded until February 12. The results of this grading are given in Tables V and VI.

TABLE V.—*Relative keeping quality of celery stored in different types of crates, as indicated by the number of stalks of the different grades found in the several types stored at Williamson, N. Y., when inspected on February 12, 1915.*

Type of crate.	Total number of stalks.	Sound.		Slightly decayed.		Badly decayed.		Worthless.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Standard	383	146	38.0	163	42.5	61	16.0	11	3.4
Partition	334	207	61.4	102	30.5	20	6.0	5	1.5
16-inch	260	152	58.4	89	34.2	14	5.3	5	1.9
14-inch	229	146	63.7	65	28.0	12	5.2	6	2.6
11-inch	181	116	64.0	53	30.0	9	5.0	3	1.6

Table V shows that the best results were secured in the 11-inch crate and the poorest in the standard crate. The bottom crate in lot No. 2 was perfect and brought up the average for that lot. Why this particular crate was so much better than any other is not known.

The difference between the keeping quality of the celery stored in this house and that stored at Hornell is probably due to the conditions under which it was handled before reaching the storage houses. The celery stored at Hornell was shipped from Arkport and had a chance to heat before being unloaded, while the celery at Williamson was hauled direct from the field to the storage house.

TABLE VI.—*Relative keeping quality of celery stored at different heights in the storage room, as indicated by the number of stalks of the different grades in the several tiers at Williamson, N. Y., when inspected on February 12, 1915.*

Tier.	Total number of stalks.	Sound.		Slightly decayed.		Badly decayed.		Worthless.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
First (bottom)	284	188	62.7	87	30.6	11	4.6	8	2.7
Second	273	160	58.6	70	25.6	31	11.4	12	4.4
Third	268	161	60.0	84	31.3	17	6.3	6	2.2
Fourth	271	147	54.2	107	39.1	16	5.9	2	.7
Fifth (top)	278	111	40.0	124	44.6	41	14.7	2	.7

The difference between the keeping quality of celery in the bottom and in the top tiers was not so great at Williamson as at Hornell, due probably to the location of the refrigerating pipes. In the Williamson house all of the pipes are overhead, while in the Hornell house they are on the side walls and over the alleyways. There is less difference in temperature at different heights in the rooms of a house with overhead refrigeration than in a house where the refrigration is on the side walls and over the alleys.

EXPERIMENTS IN 1915–16.

The celery used in the 1915–16 experiments was grown at Williamson and stored at Williamson and Hornell, N. Y. Both lots of celery were grown in the same field, handled in the same way, and harvested on October 21, 1915.

The following types of crates were used both at Hornell and at Williamson: (1) Standard crate, (2) partition-ventilated crate, (3) 16-inch crate, (4) 14-inch crate, (5) 11-inch solid-head crate.

CELERY STORED AT HORNELL.

The celery stored at Hornell was loaded into a refrigerator car in the forenoon of October 22 and shipped the same day. The car was iced on October 20, reiced at Rochester, and reached Hornell on October 25, with the bunkers from one-half to two-thirds full of ice. The celery was unloaded in the forenoon of October 26 and piled immediately.

On December 20, 1915, the celery was inspected, with the results given in Table VII. The condition of the celery on this date was about the same as that of the 1914 crop after being held in storage one month longer.

TABLE VII.—*Relative keeping quality of celery stored in different types of crates, as indicated by the number of stalks of the different grades found in the several types stored at Hornell, N. Y., when inspected on December 20, 1915.*

Type of crate.	Total number of stalks.	Sound.		Slightly decayed.		Badly decayed.		Worthless.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Standard	340	153	45.0	163	48.0	24	7.0	0	0
Partition	320	246	76.9	70	21.8	4	1.25	0	0
16-inch	286	243	85.0	38	13.2	5	1.8	0	0
14-inch	230	207	90.0	22	9.6	1	.4	0	0
11-inch	193	168	87.0	21	10.9	4	2.0	0	0

Table VII shows that the celery in the 14-inch crate kept the best and that the three types of small crates and the partition crate gave much better results than the standard crate. The celery was left in the storage house until January 21, 1916; but as there had been no other celery in the room for two or three weeks it was frosted.

The difference in the keeping quality of celery stored at different heights in the Hornell storage room is shown in Table VIII.

TABLE VIII.—*Relative keeping quality of celery stored at different heights in the storage room, as indicated by the number of stalks of the different grades in the several tiers, at Hornell, N. Y., when inspected on December 20, 1915.*

Tier.	Total number of stalks.	Sound.		Slightly decayed.		Badly decayed.		Worthless.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
First (bottom)	270	258	95.55	11	4.08	1	0.37	0	0
Second	276	228	82.60	47	17.00	1	.36	0	0
Third	268	196	72.10	71	26.50	1	.40	0	0
Fourth	281	190	68.60	88	31.30	3	1.10	0	0
Fifth (top)	274	145	52.90	97	35.40	32	11.70	0	0

It will be noticed that there was considerable difference in the keeping quality of the celery in the different tiers. The highest percentage of sound celery was in the bottom tier, and the lowest percentage in the top tier. The difference, however, was not so great in 1915–16 as in 1914–15, due to the fact that there was less celery in the room during the latter part of the storage period of 1915–16 than in the preceding year.

CELERY STORED AT WILLIAMSON.

The celery grown and stored at Williamson was harvested on October 21, hauled direct to the storage house early in the morning of October 22, and piled exactly like that in the Hornell house. This celery was examined in December, but was not sorted until January 19, 1916. The temperature maintained in the storage room was not as uniform as it had been in 1914–15, so that the celery did not keep quite as well. On several occasions there was considerable drip from the pipes, and after this the temperature was reduced to below the freezing point, which froze the outside stalks. The results of the sorting of this celery on January 19, 1916, are given in Table IX.

TABLE IX.—*Relative keeping quality of celery stored in different types of crates, as indicated by the number of stalks of the different grades in the several types stored at Williamson, N. Y., when inspected on January 19, 1916.*

Type of crate.	Total number of stalks.	Sound.		Slightly decayed.		Badly decayed.		Worthless.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Standard	334	130	39.9	172	51.5	24	7.2	8	2.4
Partition	324	200	61.7	108	33.3	13	4.0	3	.9
16-inch	284	176	62.0	91	32.0	14	4.9	3	1.0
14-inch	225	150	66.6	66	29.3	7	3.1	2	.9
11-inch	191	128	67.0	47	24.6	14	7.3	2	1.0

It will be observed that the highest percentage of sound celery was in the small crates, although the partition-ventilated crate gave almost as good results.

The difference in the keeping quality of celery stored at different heights in the Williamson storage room is shown in Table X.

TABLE X.—*Relative keeping quality of celery stored at different heights in the storage room, as indicated by the number of stalks of the different grades in the several tiers at Williamson, N. Y., when inspected on January 19, 1916.*

Tier.	Total number of stalks.	Sound.		Slightly decayed.		Badly decayed.		Worthless.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
First (bottom)	263	185	70.4	72	27.3	6	2.3	0	0
Second	277	190	68.6	77	27.8	10	3.6	0	0
Third	259	165	63.7	78	30.1	12	4.6	4	1.5
Fourth	291	154	53.0	116	40.0	15	5.1	6	2
Fifth (top)	268	90	33.6	141	52.6	29	10.8	8	3

A comparison of Tables VI and X shows that there was a greater difference in the keeping quality of the celery in the top and bottom tiers in 1915–16 than in 1914–15. This was probably due to the fact that there was more drip from the pipes and more variation in temperature in 1915–16 than in the preceding year.

SUMMARY OF RESULTS.

COMPARISON OF DIFFERENT TYPES OF CRATES.

Table XI shows the average percentage of celery of the four grades at the end of the storage period in the six types of crates used in the experiments. These figures are the averages for the six lots of celery used in the experiments during the four years 1912–13 to 1915–16, inclusive.

TABLE XI.—*Keeping quality of celery, as indicated by the average percentage of stalks of the different grades found at the close of the storage period in the several types of crates used during the four years, 1912–13 to 1915–16, inclusive.*

Type of crate.	Grades (per cent).			
	Sound.	Slightly decayed.	Badly decayed.	Worthless.
Standard	46.25	42.88	9.0	1.8
Partition	73.10	23.12	2.9	.73
16-inch (for three years only)	74.14	22.10	3.18	.58
14-inch (for three years only)	78.88	18.00	2.28	.70
11-inch solid head (for two years only)	72.66	21.83	4.75	.86
10-inch (for one year only)	97.00	3.00	.....	.....

An examination of Table XI shows that with the exception of the 10-inch crate, which was discarded after the first season because too small for practical purposes, the highest percentage of sound celery was in the 14-inch crate, followed by the 16-inch, the partition, and the 11-inch solid-head crate, in the order given. It is not quite fair to compare the 10-inch crate with the other crates, as it was used only one year, and in that particular year the celery in all of the crates kept better than in any other year.

The 14-inch and the 16-inch crates were not used the first year and the 11-inch solid-head crates were not used the first two years. It will be seen that the 11-inch crate did not give as good results as the other small crates and the ventilated crates. This was probably due to the fact that the 11-inch crate had solid heads, which excluded the air on the ends of the crates. It was observed that the stalks of celery in the ends of the 11-inch crate showed more decay than those in the ends of the crates which had slatted ends. The difference in the keeping quality of celery in the various crates is probably due to differences in temperature.

While celery temperature records were not made for all of the crates, those secured for the standard and partition crates in 1914–15 are of interest. The average temperature of the celery in the standard crate was 36.2° F. for the storage period (Oct. 24, 1914, to

Feb. 8, 1915), while the average for the partition crate was 34.2° F. for the same period. It should be noted, however, that these averages do not include the temperature for the cooling period (Oct. 21 to 24, 1914). Figure 4 shows graphically the rate of cooling of the celery in the standard and partition crates. It will

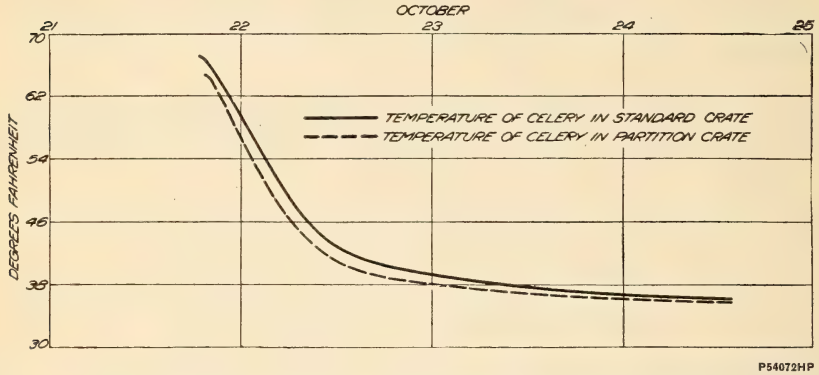

FIG. 4.—Diagram showing the drop in the temperature of celery in the standard and partition crates during the cooling period, October 21 to 24, 1914.

be noticed that the temperature of the celery was quite high when the crates were placed in storage. This is due to the fact that it was shipped in a box car, which was left standing in the railroad yards for a day after reaching the storage center. The temperature

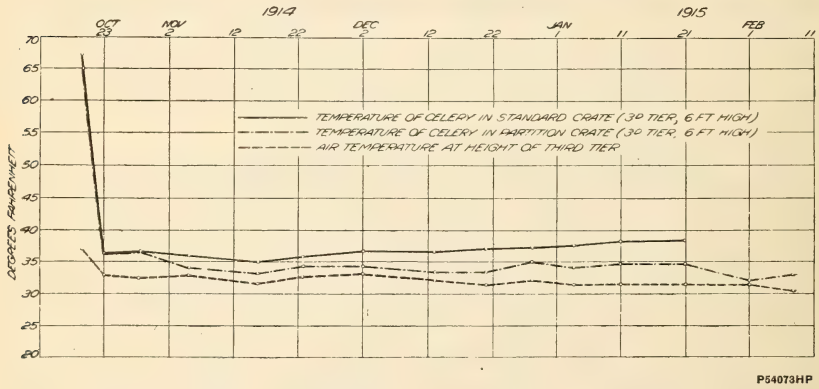

FIG. 5.—Diagram showing the temperature of celery in standard and partition crates in the third tier (6 feet high) and of the air at the same height in the storage room during the storage period from October 21, 1914, to February 8, 1915.

dropped to 36° F. from 67° F. in the standard crate and 65° F. in the partition crate in about 60 hours. Figure 5 shows in graphic form the temperature of the celery in the standard and in the partition crates and of the air at the same height for the whole storage period of 1914–15.

ESTIMATED CASH VALUE OF CELERY WHEN STORED IN DIFFERENT TYPES OF CRATES.

Table XII shows the estimated cash value of 1,000 bunches of celery, figured on the basis of the percentages given in Table XI, for the different grades of celery in each type of crate used in the experiments. The prices assigned for the different grades are as follows: 40 cents per bunch of 12 stalks for sound, 30 cents for slightly decayed, and 20 cents for badly decayed. Worthless celery consisted of stalks which were completely decayed and of no value. While the actual merchandising value of all the grades is usually higher and the difference between the grades is greater than the figures here used, it is believed that the prices assigned will serve for purposes of comparison.

TABLE XII.—*Estimated cash value of the different grades of celery in 1,000 bunches (12 stalks each) stored in each of the several types of crates, based on the percentages given in Table XI.*

Type of crate.	Value of different grades.				Total value.	Increase over standard crate.
	Sound.	Slightly decayed.	Badly decayed.	Worthless.		
Standard	$185.00	$128.64	$18.00	0	$331.64	
Partition	292.40	69.36	5.80	0	367.56	$35.92
16-inch	296.56	66.30	6.36	0	369.22	37.58
14-inch	315.52	54.00	4.56	0	374.08	42.44
11-inch solid head	290.64	65.49	9.50	0	365.63	33.99

The value of 1,000 bunches (12,000 stalks) of celery stored in 14-inch crates would be $42.44 greater than for the same number of stalks stored in the standard crate. This is at the rate of 4.2 cents per dozen stalks, or 29.4 cents per crate of seven dozen, the average number held by the standard crates used in these experiments during the four years. With this yield of 143 crates per acre, 1,000 bunches, the increase in favor of the 14-inch crate over the standard crate would be at the rate of $42.44 per acre, but with a yield of 200 crates, which is not considered very high, the increase would be $58.80 per acre, even at the prices used in Table XII.

COMPARATIVE COST OF CRATES.

While it must be admitted that the small crates cost more in proportion to their capacity, this difference is more than offset by the smaller amount of breakage. It is a well-known fact that much of the celery stored and marketed in standard crates is injured by the crates being broken in handling. In addition to this loss, the standard crates usually have to be repaired or remade before the celery reaches its destination, especially when it has been stored. Many

counts were made of the broken crates in the storage house, and it was found that at least 25 per cent needed to be repaired or remade before being shipped from the storage house to the market; in fact, in one instance a carload of 168 crates had to be repacked before being shipped to market, and 125 new crates were required. The condition of these crates when they reached the storage house is indicated in figure 6. It can readily be understood that these crates would be in a much worse condition after being handled three or four times at the storage house and at least twice more en route to market. They did not, however, survive the handling at the storage house.

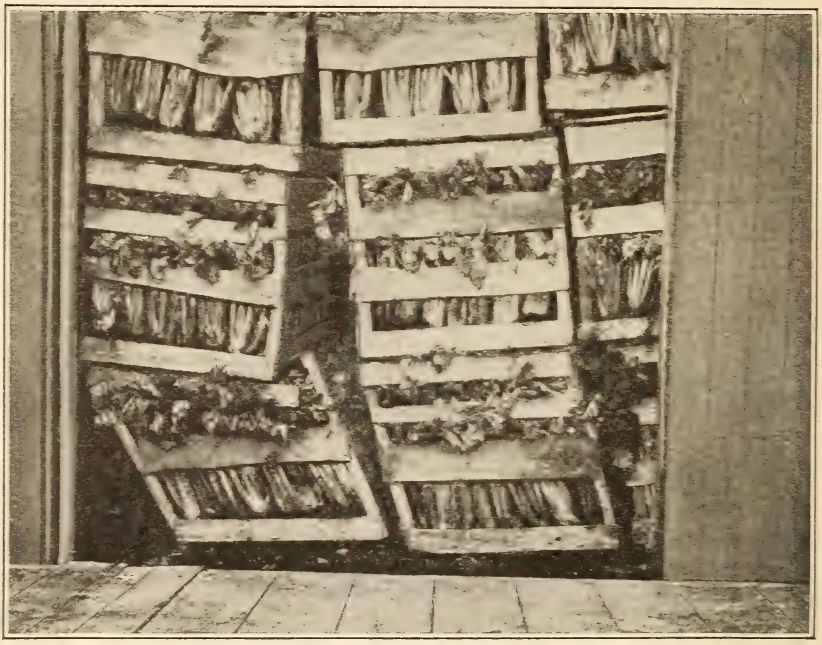

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FIG. 6.—Celery in a refrigerator car as it reached the storage house. Note the broken crates and poor method of loading. This celery was repacked before being shipped to market and 125 new crates were used.

The partition crate gave nearly as good results as the 14 and 16 inch crates as far as the keeping quality of the celery was concerned, but there is the same objection to it as to the standard crate in that it is heavy and unwieldy to handle. A crate which is nearly square and weighs 125 pounds or more when full is hard to handle, and this is one reason why so many slats are broken in loading and unloading the filled crates. One crate is often dropped with considerable force on another crate, which results in the breaking of the top slats of the one or the bottom slats of the other. In lifting the large crates by their top slats the slats are often broken or pulled off. A broken crate does not stack well in a car or in the storage house, often tipping

over in such a way as to crush the celery in the crates below. Much of the loss due to the breakage of the crates and the injury to the celery can be obviated by the use of smaller crates. The small crates are not so wide, and for this reason are more easily handled. They are made of the same material, and as they do not carry as much weight as the standard crate, seldom break in handling.

The average number of stalks of celery per crate in the 25 crates of the 14-inch size used in the experiments was 52.2, or 4.35 dozen; in the same number of 16-inch crates 61 stalks, or 5.1 dozen; while the average for the standard crate was 84 stalks, or 7 dozen. The comparative cost of the crates needed to hold 1,000 bunches (12,000 stalks) of celery, based on the capacity of the different-sized crates as given above and figured at 18 cents for the standard crate, would be about as follows:

143 standard crates, at 18 cents each	$25.74
196 16-inch crates, at 17 cents each	33.32
230 14-inch crates, at 16 cents each	36.80

As already mentioned, the difference in cost in favor of the standard crate would be more than offset by the expense of repairing them and the loss due to the injury to the celery itself. The appearance of the crate often determines the selling price of the celery. In other words, one lot of celery in good crates often brings from 50 cents to $1 more per crate than a similar lot in broken and patched crates. The time lost in repacking the celery when the crates are very badly broken should also be taken into consideration.

It might be argued that the storage charges for the small crates would be higher in proportion to their capacity than for the standard crates. While this might be true, many storage-house managers have indicated a willingness to base their charges on cubic capacity. Nearly all of the storage-house men interviewed favor the small crates, because they are easier to handle, less liable to get broken, and keep the celery in better condition.

Some growers have said that it would be difficult to sell celery in small crates because the trade is accustomed to the large crate and their prices are based on the latter. While it is true that most of the truck-crop celery grown in the North and in California is packed in large crates, all of the Florida celery is put up in small crates, 10 or 12 inches wide by 24 inches long. That small crates of celery are in demand on the market is evidenced by the sale of a carload of celery which included 127 large standard crates (22 by 24 inches) and 56 small (12-inch) crates.[1] These two lots of celery were grown and packed by the same grower, stored in the same room, and

[1] The writer is indebted to Mr. Charles P. Russell, of Williamson, N. Y., for the information in regard to this carload of celery.

put on the market the same day. The price received for the 127 large crates averaged $3.93 per crate, and for the 56 small crates $2.576 per crate. The grower of this celery was at the New York market on January 10, when it was sold, and stated that the buyers seemed particularly pleased with the small crates, because of their size and the good condition of the celery they contained. The increased price received for the celery in the small crates was probably due partly to the fact that it was in better condition than that in the standard crates and partly to the fact that the small crate was of a more convenient size to handle. The small crate should be in demand for restaurants and retail stores.

COMPARISON OF THE KEEPING QUALITY OF CELERY STORED AT DIFFERENT HEIGHTS IN THE STORAGE ROOM.

No record was made of the difference in the keeping quality of celery stored at different heights in the storage room during the first two years of the experiments, and as the two storage houses in which the celery was stored during the last two years have different methods of piping, the results are tabulated separately. In the Hornell house the refrigerating pipes are located on the side walls near the ceiling and over the passageways, while in the Williamson house the pipes are distributed on the ceiling. The results for the past two years are given in Table XIII. It should be remembered that each tier consists of one crate each of the different types.

TABLE XIII.—*Keeping quality of celery stored at different heights in the storage houses at Hornell and at Williamson, N. Y., as indicated by the average percentage of celery of different grades in the several tiers, for the two years, 1914–15 and 1915–16.*

Tier.	Grades at Hornell, N. Y. (per cent).				Grades at Williamson, N. Y. (per cent).			
	Sound.	Slightly decayed.	Badly decayed.	Worthless.	Sound.	Slightly decayed.	Badly decayed.	Worthless.
First (bottom)	92.75	6.79	0.33	0	66.55	28.95	3.45	1.35
Second	75.65	24.00	.33	0	63.60	26.70	7.50	2.20
Third	70.45	28.60	.45	0	61.85	30.70	5.45	1.85
Fourth	59.85	39.20	.95	0	53.60	39.55	5.50	1.35
Fifth (top)	42.00	39.80	17.95	.25	36.80	48.60	12.75	1.85

Table XIII shows that there was considerable difference in the keeping quality of celery stored in the different tiers at Hornell, the bottom tier being the best and the top the worst—in fact, the bottom tier contained 50 per cent more sound celery than the top tier.

A comparison of the figures in Table XIII shows that there was not as much difference in the keeping quality of celery stored at different heights in the storage house at Williamson as there was in the Hornell house. The difference in sound celery between the top and

bottom tiers in the Williamson house was only about 30 per cent, whereas in the Hornell house the difference was 50 per cent. A possible reason for this difference is that in the Williamson house there was a more even distribution of temperature. It should be borne in mind, however, that the results in the two storage houses during 1914–15 and 1915–16 are not exactly comparable, as the celery was not graded at the same time. The celery stored at Hornell in 1914–15 was graded on January 22, 1915, and that stored at the same place during the past season was graded on December 20, 1915. The celery stored at Williamson during the two seasons was graded on February 12, 1915, and on January 19, 1916. In other words, the celery stored at Williamson was kept in storage nearly a month longer than that stored at Hornell. It is believed that the drip from the pipes in the Williamson house had more influence on the keeping quality of celery in the top tier of crates than the temperature. In other words, the difference between the celery in the top and bottom tiers of crates is due more to moisture in the top tier than to the difference in temperature at different heights. It is usually possible to so regulate the temperature that there is very little drip from the pipes, but during the season of 1915–16 this was not accomplished in the room where the experimental celery was stored. During the previous storage season the room was dry nearly all the time, and there was not a great difference in the amount of decay in the different tiers. There was a greater difference between the amount of sound celery in the fourth and fifth tiers than between that in the first and fourth tiers, as is shown in Table XIII.

The figures already given to show the difference in keeping quality of celery stored at different heights in the storage room do not show the variation due to the different types of crates. It seems desirable to compare the keeping quality of celery stored at the same heights in the different types of crates and at different heights in the same type of crates. Tables XIV and XV give these data for two lots of celery, one lot stored at Hornell and the other at Williamson, N. Y., during the storage period of 1914–15.

Table XIV shows that there was not a great difference in the different types of crates in the first tier, except in the partition crate. The high percentage of sound celery in the partition crate is due to the fact that in the Williamson house the celery in this crate was practically perfect, due to some unknown cause. In the fifth, or top, tier there was the greatest difference in the keeping quality of celery in the various types of crates. The partition crate contained 44.2 per cent more sound celery than the standard crate, the 16-inch crate 61.1 per cent more, and the 14-inch crate 76.9 per cent more. The standard crate contained a much larger percentage of badly decayed celery than any of the other crates.

TABLE XIV.—*Keeping quality of celery, as indicated by the average percentage of stalks of the different grades found in the several types of crates stored at different heights in the storage room, for two lots, at Hornell and Williamson, N. Y., respectively, in 1914–15.*

Tier and type of crate.	Grades of two lots (per cent).			
	Sound.	Slightly decayed.	Badly decayed.	Worthless.
First (bottom):				
Standard	64.9	30.0	2.6	2.6
Partition	96.7	3.3	0	0
16-inch	77.7	17.6	2.8	1.8
14-inch	79.6	16.5	1.9	1.9
Second:				
Standard	56.7	34.6	7.2	1.3
Partition	69.6	21.6	5.6	3.2
16-inch	71.7	23.0	3.5	1.8
14-inch	74.0	18.0	6.0	2.0
Third:				
Standard	50.0	43.2	6.2	.5
Partition	74.0	24.4	.76	.76
16-inch	77.0	20.2	1.8	.9
14-inch	82.3	11.4	4.1	2.1
Fourth:				
Standard	38.9	53.7	6.2	1.2
Partition	59.5	37.4	3.0	0
16-inch	69.4	28.6	2.0	0
14-inch	78.1	21.9	0	0
Fifth (top):				
Standard	6.2	63.0	29.0	1.2
Partition	50.4	41.3	8.4	0
16-inch	67.3	29.9	2.8	0
14-inch	83.1	16.8	0	0

TABLE XV.—*Keeping quality of celery, as indicated by the average percentage of stalks of the different grades found at different heights in the storage room when stored in the several types of crates, for two lots, at Hornell and Williamson, N. Y., respectively, in 1914–15.*

Type of crate and tier.	Grades of two lots (per cent).			
	Sound.	Slightly decayed.	Badly decayed.	Worthless.
Standard:				
First (bottom)	64.9	30.0	2.6	2.6
Second	56.7	34.6	7.2	1.3
Third	50.0	43.2	6.2	.6
Fourth	38.9	53.7	6.2	1.2
Fifth (top)	6.2	63.0	29.0	1.2
Partition:				
First (bottom)	96.7	3.3	0	0
Second	69.6	21.6	5.6	3.2
Third	74.0	24.4	.76	.76
Fourth	59.5	37.4	3.0	0
Fifth (top)	50.4	41.3	8.4	0
16-inch:				
First (bottom)	77.7	17.6	2.8	1.8
Second	71.7	23.0	3.5	1.8
Third	77.0	20.2	1.8	.9
Fourth	69.4	28.6	2.0	0
Fifth (top)	67.3	29.9	2.8	0
14-inch:				
First (bottom)	79.6	16.5	1.9	1.9
Second	74.0	18.0	6.0	2.0
Third	82.3	11.4	4.1	2.1
Fourth	78.1	21.9	0	0
Fifth (top)	83.1	16.8	0	0

An examination of Table XV shows that the greatest difference in the keeping quality of celery between the top and bottom tiers was

in the standard crate. The bottom tier contained 64.9 per cent of sound celery and the top tier only 6.2, a difference in favor of the former of 58.7 per cent. A study of Tables XIV and XV shows that the great difference in the keeping quality of celery stored at different heights, as shown in Table XIII, is due largely to the standard crate. In other words, with the small crates and the partition crates the difference between the different tiers is not great.

The difference in the keeping quality of celery at various heights in the storage room and in the several types of crates is probably

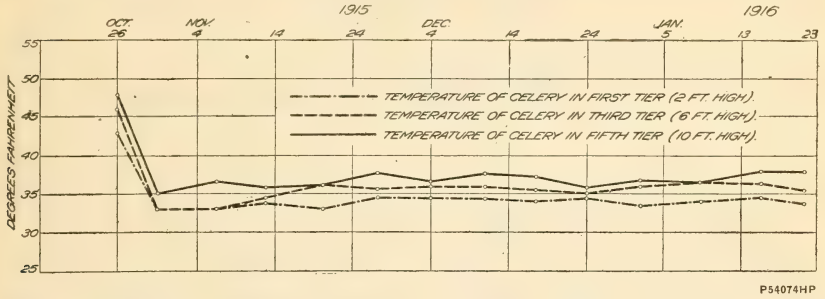

FIG. 7.—Diagram showing the temperature of celery in the center of standard crates at different heights in the storage room, during the storage period from October 26, 1915, to January 21, 1916.

due to differences in temperature. Figure 7 shows graphically the difference in the temperature of celery in the standard crates stored at different heights in the storage house in 1915–16. The temperature was recorded by means of air-soil thermographs, the soil bulb being placed in the center of the crate. Table XVI shows the average temperature of the celery in the standard crates and of the air at different heights in the storage room for the storage period from October 26, 1915, to January 21, 1916.

TABLE XVI.—*Average temperature of celery in the standard crates and of the air in the storage house at Hornell, N. Y., from October 26, 1915, to January 21, 1916.*

Tier.	Temperature (°F.).	
	Of celery.	Of air.
First (bottom)	33.9	31.6
Third	35.8	32.8
Fifth (top)	36.6	33.8

Table XVI shows that the average temperature of the celery in the third tier was 1.9 degrees higher and that in the fifth was 2.7 degrees higher than that in the first tier. The temperature of the air was 1.2 degrees higher in the third and 2.2 degrees higher in the fifth tier than in the first tier. By comparing the air temperature and the

celery temperature at the same heights in the room, it will be seen that the celery averaged 2.7 degrees higher than the air. Figure 8 shows graphically the air temperature at different heights in the storage room for the storage period, October 26, 1915, to January 21, 1916.

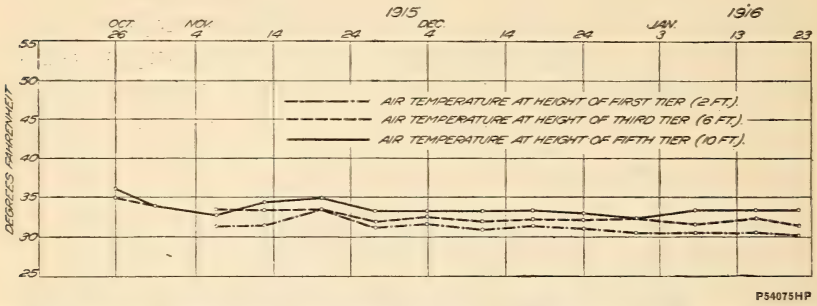

FIG. 8.—Diagram showing the temperature of the air at different heights in the storage room during the storage period from October 26, 1915, to January 21, 1916.

Table XVII shows the average temperature of the celery in the standard and partition crates at the same height (third tier) and the air temperature at different heights for the storage period of 1914–15.

TABLE XVII.—*Average temperature of celery in standard and partition crates at the height of the third tier and of the air at different heights in the storage house at Hornell, N. Y., for the storage period of 1914–15.*

Tier.	Air temperature at different heights.	Type of crate.	Celery temperature (third tier).
	°F.		°F.
First (bottom)	31.5	Standard	36.2
Third	32.1	Partition	34.2
Fifth (top)	33.9		

Table XVII shows that the average air temperature at the height of the third tier was 0.6 of 1 degree higher and at the height of the fifth tier 2.4 degrees higher than at the height of the first tier. The average temperature of the celery in the standard crate was 2 degrees higher than that in the partition crate and 4.1 degrees higher than the air at the same height (fig. 5). Figure 9 shows graphically the air temperature at different heights in the storage room for the storage period, October 21, 1914, to February 8, 1915.

The rate of cooling of celery in standard crates at different heights in the storage house in 1915–16 is shown in figure 10, which indicates that the temperature began to drop in the bottom crate sooner than in the third-tier and top crates. A comparison of figures 4 and 10 shows that the temperature of the celery placed in storage October

21, 1914, was higher than that stored in the same house on October 26, 1915. The latter lot of celery was shipped to Hornell in a refrigerator car which had been iced before loading and was reiced in transit, while the 1914 lot was shipped in a box car and became somewhat heated before being unloaded.

While the temperature records given in this paper are not as complete as desired, a study of all the charts in connection with the

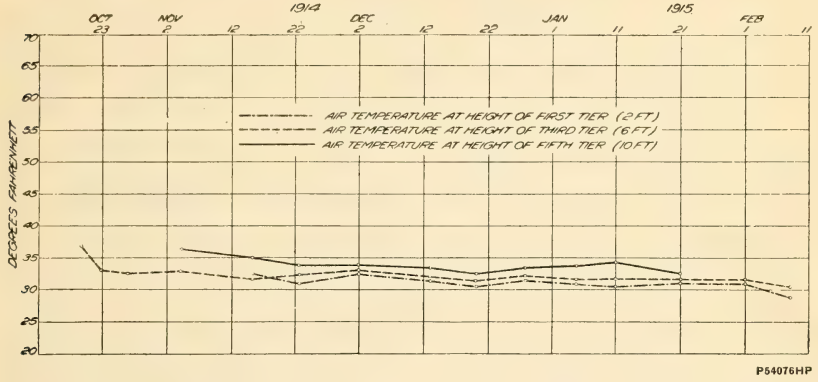

FIG. 9.—Diagram showing the temperature of the air at different heights in the storage room for the storage period from October 21, 1914, to February 8, 1915.

keeping quality of celery in different types of crates and at different heights in the storage house shows quite clearly that there is a close relation between the temperature and the deterioration of the crop in storage. It will be noticed that the temperature was higher in the standard crate than in the partition crate (figs. 4 and 5) and that the celery and air temperature near the top of the room

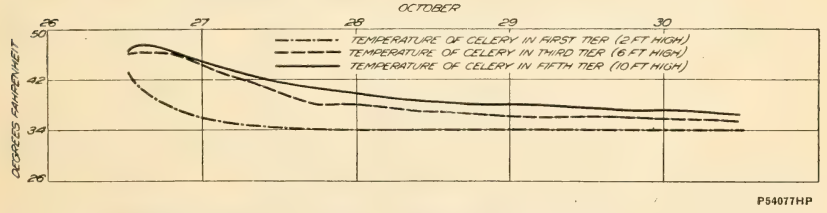

FIG. 10.—Diagram showing the drop in the temperature of celery in the center of standard crates at different heights in the storage room for the cooling period, October 26 to 30, 1915. Note that the temperature in the bottom crate began to drop almost immediately.

was always higher than near the bottom of the room (figs. 7 and 8). In every instance the largest proportion of decay was where the temperature was the highest. For this reason celery should be stored in crates in which there is the least difference between the air and celery temperature. In a large crate without a ventilator the tem-

perature of the celery in the center usually is several degrees higher than the temperature of the air. In the standard crate, 22 inches wide, the center of the celery is 11 inches from an air space, while in a crate 14 inches wide the center of the celery is only 7 inches from an air space.

The cold air being heavier than the warm air it naturally falls to the low levels and the warm air rises. An artificial system of circulation tends to equalize the temperature and prevents the formation of cold-air pockets. In most storage houses, the aim is to maintain a temperature of about 32° F.; but as the thermometers are usually placed a few feet from the floor they do not record the temperature near the top of the room, near the floor, or in the corners. Often when the thermometers register 32° F. the actual temperature at the height of the top tier of crates is 35° or 36° F., and near the floor and in the corners of the room the temperature is 2 or 3 degrees below the freezing point. The aim of the manager of the storage house should be to equalize the temperature and keep it as low as possible without allowing the celery to freeze severely. Slight freezing does no damage if the temperature is not raised quickly above the freezing point. In most storage houses, a temperature which does not freeze the outside stalks of celery in the lower tiers of crates is too high to maintain the celery in the top tiers in a satisfactory condition.

It is suggested that thermometers be placed at different heights throughout the storage rooms, in the corners as well as in the center passageways. All of these thermometers should be tested, and when the temperature shows much variation in the different parts of the room the air should be set in motion. This can be done by using fans or blowers, or by opening doors on opposite sides of the room when the outside temperature is about the same as the temperature in the storage house. Some houses are equipped with suction fans which draw off the warmer air at the top of the room. Cold air is then forced in.

SUMMARY.

Celery is one of the important truck crops grown in the United States, having a farm value in 1909 of $3,922,848.

Six States—New York, Michigan, Massachusetts, Ohio, Pennsylvania, and New Jersey—produce about two-thirds of the celery crop, and a considerable portion of this is stored for a period of one to three months.

The old method of storing celery in the field and in houses of the cellar and semicellar type is not satisfactory, because temperature and moisture conditions can not be controlled.

The storage of celery in cold-storage warehouses is a comparatively new undertaking, and for this reason very little definite information is available on the subject.

In preliminary studies it was observed that celery stored in the large crates always began to decay in the center, and also that there was considerable injury to the celery due to the breaking of the crates.

As the celery decayed worse in the center of the crate than elsewhere, small crates and ventilated crates were used in the experiments. In every instance the decay was much less in the small and partition crates than in the standard crates.

Of the crates used during two or more years, the 14-inch crate gave the best results, followed by the 16-inch crate, the partition crate, and the 11-inch solid-head crate, in the order given.

The estimated value of 1,000 bunches (12 stalks each) of celery stored in the different types of crates is $331.64 for the standard crate, $367.56 for the partition crate, $369.22 for the 16-inch crate, $374.08 for the 14-inch crate, and $365.63 for the 11-inch solid-head crate.

The small crates cost a little more than the standard crate in proportion to their capacity, but this is more than offset by the smaller percentage of breakage.

The small crates are preferred by many storage-house managers and handlers of celery because of the ease of handling and the smaller amount of breakage.

In a market test made in January, 1916, celery in small crates sold for a much higher price than similar celery in standard crates handled in exactly the same way.

Celery in the top tier of crates showed a much larger proportion of decay at the end of the storage period than that in the lower tiers.

There was a greater difference in the keeping quality of celery in the different tiers where the standard crate was used than where the other crates were employed.

The difference in the keeping quality of celery in the different types of crates and at various heights was probably due to the difference in temperature and rate of cooling.

The air temperature at the height of the fifth tier averaged 2.4 degrees higher than at the height of the first tier during the storage period of 1914–15. The temperature of the celery in the standard crate averaged 2.7 degrees higher at the height of the fifth tier than at the height of the first tier during the storage period of 1915–16.

The temperature of the celery in the standard crate averaged 2 degrees higher than in the partition crate and 4.1 degrees higher than the air at the same height.

In most storage houses the temperature is recorded by means of thermometers placed a few feet from the floor. These do not show the temperature near the ceiling.

In many instances, when the thermometers register 32° F. within 4 feet of the floor the temperature is 35° to 36° F. near the ceiling.

Thermometers should be placed at various heights in the storage room and in the corners as well as in the passageways. When there is much variation in temperature in different parts of the room the air should be set in motion.

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1917